Description

METHOD AND APPARATUS FOR CONTROLLING REGENERATION OF A PARTICULATE FILTER

Technical Field

[01] This invention relates generally to particulate filters, and more particularly, to controlling the regeneration of particulate filters.

Background

[02] Particulate filters for engine exhaust are gaining importance as engine manufacturers seek to reduce emissions. Particulate filters are used to filter out particulate matter from the engine's exhaust stream, and to periodically regenerate when the filter reaches a certain degree of clogging. Regeneration of the filter is typically accomplished by increasing the temperature of the particulate filter to a point where the accumulated particulates are burned off, thereby unclogging the filter.

[03] Catalysts of various compositions are frequently used to elevate the temperature of the particulate filter. Catalysts, however, typically only function well when they are above their respective "light off" temperature. The "light off" temperature for a catalyst is typically a temperature above which the catalyst is able to convert unburned hydrocarbons at some predetermined efficiency. Typically at temperatures below the "light off" temperature the catalyst converts a negligible amount of hydrocarbons, while at temperatures above the "light off" temperature, the catalyst may operate at a substantially higher efficiency.

[04] The unburned hydrocarbons may be delivered to the catalyst through a variety of ways, such as, for example, injecting a shot of diesel fuel after substantial combustion within a cylinder has occurred. The diesel fuel then

exits the cylinder through the exhaust valve and reaches the catalyst in relatively unchanged form.

[05] Control of the temperatures of the catalyst and particulate filter have been relatively crude, and a better techniques and devices for performing this function are desired.

Summary of the Invention

[06] The present invention provides apparatuses and methods for regenerating a particulate filter. A first temperature corresponding to a temperature of a catalyst that is thermally coupled with a particulate filter is determined. A second temperature corresponding to the temperature of the particulate filter is determined. Substantially no unburned hydrocarbons are delivered to the catalyst when the first temperature is below a first threshold and unburned hydrocarbons are delivered to the catalyst when the first temperature is above the first threshold and the second temperature is below a second threshold.

Brief Description of the Drawings

[07] Figure 1 is a side view of a cylinder of an engine along with an associated particulate filter and control devices therefore according to one embodiment of the invention.

[08] Figure 2 is a flow chart according to one embodiment of the invention.

Detailed Description

[09] Figure 1 is a side view of a cylinder 10 of an engine 12 along with an associated particulate filter 14 and control devices therefore according to one embodiment of the invention. Although only a single cylinder 10 is shown for purposes of illustration, the invention may be equally applicable to multi-cylinder engines, as well as rotary-engines. The invention may be practiced in both two and four stroke combustion cycles. The engine 12 includes an intake air

passageway 16 and at least one intake valve 18 disposed in the intake air passageway and operable to fluidly connect the intake air passageway 16 with the cylinder 10 by ways known to those skilled in the art.

[10] A piston 20 may be disposed within the cylinder 10 and reciprocates, delivering power to a crank shaft 22 during the combustion cycle by ways known to those skilled in the art.

[11] A fuel delivery device, such as a fuel injector 24 may be fluidly coupled with the cylinder 10 to provide a combustible fuel as a function of a control signal ("CONTROL") by ways known to those skilled in the art. The fuel injector 24 may also serve as a hydrocarbon delivery system as will be described further below. Other types of hydrocarbon delivery systems delivering the same or other sources of hydrocarbons may be used in addition to or instead of fuel injector 24 as will become evident from the below description. Any of a variety of hydrocarbons known to those skilled in the art may be delivered, such as, gasoline, natural gas, kerosene, and crude oil. Furthermore, in other embodiments of the invention, an extra in-exhaust fuel injector (not shown) or other hydrocarbon delivery device could be used to deliver the hydrocarbons in lieu of or in addition to the fuel injector 24.

[12] At least one exhaust valve 26 may be fluidly coupled with the cylinder 10 and may be operable to couple the cylinder 10 with an exhaust path 28 by ways known to those skilled in the art.

[13] A catalyst 30 may be coupled with the exhaust path 28 to receive exhaust gases from the cylinder 10. The catalyst 30 is typically selected to convert hydrocarbons ("HC") to heat by ways known to those skilled in the art. The catalyst 30 may be any of a variety of materials known to those skilled in the art.

[14] The catalyst 30 typically has a "light-off" temperature. The "light-off" temperature is typically a temperature at which the catalyst converts a desired percentage of hydrocarbons to heat, *e.g.*, a particular efficiency.

[15] A first temperature sensor 32 may be thermally coupled with the catalyst 30 to determine a first temperature ("T1") indicative of a temperature of the catalyst 30. The first temperature sensor 32 may be operable to transmit a first temperature signal as a function of the first temperature. As a practical matter, the first temperature sensor 32 may be disposed in the exhaust path 28 in close proximity to the catalyst 30. Other locations that provide a temperature correlated to the temperature of the catalyst 30 may also be used.

[16] The particulate filter 14 is typically thermally coupled with the catalyst 30. The particulate filter 14 is operable to filter particulate matter from the exhaust gases emitted from the cylinder 10 by ways known to those skilled in the art.

[17] During filtration, the particulate filter 14 accumulates the particulate matter from the exhaust gas. Over time, the particulate filter 14 may become partially or completely clogged and require regeneration.

[18] Regeneration of the particulate filter 14 may be achieved by elevating the temperature of the particulate filter to a temperature sufficient to burn-off the accumulated particulates. This temperature is typically 450-600 degrees Celsius, although the range may vary.

[19] A second temperature sensor 34 may be thermally coupled with the particulate filter 14 to determine a second temperature indicative of a temperature of the particulate filter. The second temperature sensor 34 may be operable to transmit a second temperature signal as a function of the second temperature. As a practical matter, the second temperature sensor 34 may be disposed in the exhaust path 28 in close proximity to the particulate filter 14. Other locations that provide a temperature correlated to the temperature of the particulate filter 14 may also be used.

[20] A regeneration controller 36, such as an electronic engine control module ("ECM") or fuel injector control module, may be coupled with the first and second temperature sensors to receive the first and second temperature

signals. The regeneration controller 36 may be any of a variety of type of ECM's known to those skilled in the art. The controller 36 may be operable to transmit the control signal CONTROL as a function of the first and second temperature signals, as will be further explained below.

[21] The regeneration controller may be further operable to determine, or receive a signal indicative of, when regeneration of the particulate filter 14 is desired. This may be accomplished by any of a variety of ways known to those skilled in the art.

[22] In operation, when regeneration of the particulate filter 14 is desired, the regeneration controller 36 causes the hydrocarbon delivery system to deliver unburned hydrocarbons to the catalyst 30. In the illustrated example, the regeneration controller 36 transmits an appropriate control signal CONTROL to fuel injector 24 to cause the fuel injector 24 to inject fuel in the form of a second shot, for example, into the cylinder late in the combustion cycle, or after significant or all of the conventional combustion occurs.

[23] When the exhaust valve 24 opens during the exhaust stroke, the fuel, a.k.a. unburned hydrocarbons, passes into the exhaust path 28, and to the catalyst 30. The unburned hydrocarbons cause the catalyst 30 to heat up, thereby heating the particulate filter 14 to a temperature that burns off at least some of the accumulated particulates, regenerating the particulate filter 14. The temperature of the particulate filter may be held at this regeneration temperature for as long as desired, typically until the majority of accumulated particulates have been burned off.

[24] In one embodiment of the invention, it may be desirable to only deliver unburned hydrocarbons to the catalyst 30 when the first temperature T1 is above the "light-off" temperature of the catalyst. This prevents unburned hydrocarbons from passing through the catalyst by virtue of the fact that they are not converted to heat, and out into the atmosphere.

[25] The regeneration controller 36 may also be used for closed loop control of the second temperature T2. By determining the second temperature T2, the regeneration controller 36 may control the amount of hydrocarbons delivered into the exhaust stream, and thereby to the catalyst. Typically the more hydrocarbons delivered, the hotter the catalyst 30 will get, and the hotter the particulate filter and the second temperature T2 will get. Similarly, if the second temperature T2 should become higher than desired, the regeneration controller 36 can reduce the amount of hydrocarbons delivered into the exhaust stream and to the catalyst 30.

[26] Figure 2 is a flow chart 50 according to one embodiment of the invention. In block 52 the first temperature T1 corresponding to the temperature of the catalyst 30 is determined.

[27] In block 54, the first temperature T1 is compared with the "light-off" temperature of the catalyst 30. If the first temperature T1 is not greater than or equal to the "light-off" temperature, control passes back to block 52. If the first temperature T1 is greater than or equal to the "light-off" temperature, control passes to block 56.

[28] In block 56, the second temperature T2 corresponding to the temperature of the particulate filter 14 is determined.

[29] In block 58, the second temperature T2 is controlled via a closed loop control system to a desired temperature, such as the regeneration temperature of the particulate filter. The closed loop system may be any of a variety of closed loop control systems known to those skilled in the art.

Industrial Applicability

[30] Embodiments of the invention may be used to control the regeneration of a particulate filter using a catalyst and unburned hydrocarbons. By monitoring the first temperature T1, the regeneration controller 36 can ensure that unburned hydrocarbons are only added to the exhaust stream during conditions allowing the catalyst 30 to convert them to heat. In addition, the

regeneration controller 36 can use the second temperature T2 as feedback to ensure that the proper amount of hydrocarbons are added to the exhaust path to achieve and maintain the particulate filter at a temperature that will cause regeneration.

[31] From the foregoing it will be appreciated that, although specific embodiments of the invention have been described herein for purposes of illustration, various modifications may be made without deviating from the spirit or scope of the invention. Accordingly, the invention is not limited except as by the appended claims.